United States
Department of
Agriculture

Forest Service

Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401

Research Paper
INT-300

January 1983

Lifting, Storage, Planting Practices Influence Growth of Conifer Seedlings in the Northern Rockies

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RESEARCH SUMMARY

In two studies in northern Idaho, Engelmann spruce, lodgepole pine, and western larch nursery stock were lifted and stored under a variety of regimes and planted throughout the spring planting season. Lifting-storage regimes included: (1) fall lifting and storage at 28° F (-3° C) until planted; (2) spring lifting and storage at 34° to 38° F (10° to 3° C) until planted; (3) spring lifting and snow cache storage; and (4) spring lifting just prior to planting. Planting date had the strongest influence on survival and growth with early plantings performing better than late plantings. Stock lifted in the fall and stored at subfreezing temperatures survived and grew as well or better than stock conventionally lifted and stored, especially when planted late in the season. Larch benefited most from fall lifting and overwinter storage at subfreezing temperatures, followed by spruce and lodgepole pine. Some fall lifting and overwinter storage at 28° F is now a standard procedure at the Coeur d'Alene Nursery.

Cover Photo: The Coeur d'Alene Nursery, Coeur d'Alene, Idaho, as it appeared when newly completed in 1963. This USDA Forest Service Nursery is administratively attached to the Idaho Panhandle National Forests and provides forest tree planting stock to the National Forests of the Northern Rocky Mountains. The Nursery has cooperated with the Intermountain Experiment Station in many studies to improve nursery and reforestation methods.

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INTRODUCTION

Until 1976, the Coeur d'Alene Nursery, like most northern temperate zone nurseries, lifted all of its coniferous bare root stock in the early spring for later spring planting. Typically stock has been lifted in March, placed in cold storage (34° to 38° F [1° to 3° C]), and planted when conditions were favorable at the planting site. With the large geographical and elevational range served by the nursery, the planting season can extend into early July. Although every effort has been made to lift stock while it was still dormant and to plant as early as possible, weather conditions and the magnitude of the lifting, sorting, and packing job often resulted in undesirable delays.

Investigations in Canada, the northeastern United States, and Europe have shown that trees can be lifted in the fall and stored overwinter (Hocking and Nyland 1971). This is feasible when storage temperatures are lowered to below freezing to reduce physiological activity and pathogen growth (Nyland 1974a), and if the trees are protected from desiccation by a suitable vapor barrier (Nyland 1974b). The potential advantages of fall lifting and frozen storage of nursery stock prompted study of the technique at the Coeur d'Alene Nursery in 1972.

This paper reports the results of nursery trials in 1972 and a limited field trial in 1973.

The study was conducted to obtain comparative information on the effects of storage conditions, in combination with various spring planting dates, on the survival of outplanted stock. The primary objective was the testing of overwinter storage at subfreezing temperatures. Other temperature regimes were used as controls or as additional alternatives to conventional storage methods. Because planting normally extends over a period of 2½ to 3 months in the Northern Rocky Mountain area, planting date was also studied as an interactive variable.

PHASE I. NURSERY-BASED SURVIVAL COMPARISONS, 1972

Methods

Three coniferous species, Engelmann spruce (*Picea engelmannii* Parry), lodgepole pine (*Pinus contorta* Dougl. var *murrayana* [Grev. and Balf.] Engelm.) and western larch (*Larix occidentalis* Nutt.) were selected for trial. Lodgepole pine and spruce were used because of the long storage periods usually involved; larch because of past storage difficulties.

The objective of this initial study was to obtain comparative information on the effects of storage conditions, in combination with various spring planting dates, on the survival of outplanted stock. Storage regimes were as follows:

1. **Frozen**.—On November 17, 1971, 1,125 trees of each species were lifted and sealed in plastic (4-mil polyethylene) bags, put into preconditioning refrigerated storage at 34° F (1° C) to 38° F (3° C) for 2 days, at 32° F ± 1° (0° C) for 1 week, and finally at 28° F ± 2.5° (-2° C ± 1°) for the remainder of the storage period. Trees were tied into 25-tree bundles, then stored with three bundles (75 trees) per bag. At each planting date the following spring the requisite number of seedlings of each species were removed from the freezer 5 days before planting and placed in refrigerated storage at 34° to 36° F (1° to 2° C) to thaw. By calling this treatment "frozen" we mean that the ambient storage temperature was subfreezing. Tree tissue temperature was not determined.

2. **Refrigerated**.—On March 18, 1972, 1,125 trees of each species were lifted and placed in refrigerated storage (34° to 36° F [1° to 2° C]) in the tree storage rooms at the nursery. These trees were packaged in polyethylene-lined Kraft bags. This was the standard procedure then in use at the Nursery. Wet sphagnum moss was placed around the seedlings' roots.

3. **Snow cached.**—On March 18, 1972, 1,125 trees of each species were lifted, packaged, and stored as described in 2 above. Five days later these seedlings were placed in a snow cache near Coeur d'Alene at an elevation of 4,800 ft (1 463 m). The cache was constructed according to methods described by Dahlgren and others (1974). At each subsequent planting date the cache was opened, stock removed, and the cache resealed. The cache was still usable in late July, long after the last stock had been removed.

4. **Fresh.**—Seedlings were freshly lifted just prior to each planting, refrigerated at 34° to 36° F (1° to 2° C) overnight, and planted the next day.

Stock survival after planting was tested using the Variable-Moisture-Stress-Plot Technique described by Boyd and others (1972). Trees were planted on five dates: April 4, April 25, May 16, June 6, and June 27, 1972 (table 1). On each date, three 25-tree bundles of each species from each storage treatment were planted in each of three moisture stress plots, as follows:

Table 1.—Length of nursery stock storage prior to planting, 1971-72

Planting date	Length of storage: Snow cached	Refrigerated	Frozen
	Days		
April 4	13	18	139
April 25	34	39	159
May 16	55	60	180
June 6	76	81	201
June 27	97	102	222

1. **Low stress.**—Soil moisture was maintained above 30 percent of field capacity by irrigation and periodic removal of weed competition.

2. **Moderate stress.**—Soil moisture was allowed to deplete to natural levels. Weed competition was periodically removed. Plots were not irrigated.

3. **Extreme stress.**—Soil moisture was allowed to deplete to natural levels. Weed competition was undisturbed. Plots were not irrigated.

Seedlings were planted 12 inches (30.48 cm) apart, within plowed furrows 18 inches (45.72 cm) apart. Transplanting boards were used to facilitate planting. Soil moisture in the plots was monitored during the summer to aid in timing of irrigation and weeding.

Until all five plantings were completed, soil moisture in all the stress plots was kept at or above 50 percent availability by a temporary watering system. After July 1, the moderate and extreme stress plots were not watered. Low and moderate stress plots were weeded every 4 weeks. The low stress plot was irrigated five times and each watering lasted an average of 6 hours. An average of 0.96 inches (2.45 cm) of water was applied at each watering. Distribution of rainfall during the planting and stress period is shown in figure 1.

Survival tallies were made on August 1, September 2, and October 5, 1972. Analysis of variance for a factorial design was applied to the October 5 data of each species with tests for survival differences attributable to storage, planting date, stress level, and possible interactions among these main variables. Survival percentages were transformed to the arc sin $\sqrt{\text{percent}}$ for analysis.

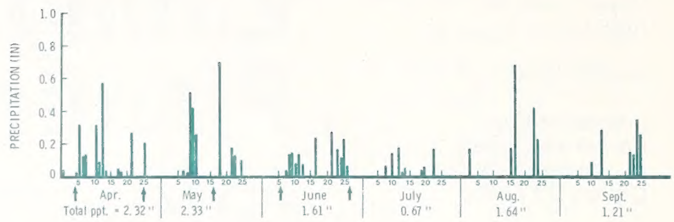

Figure 1.—Growing season precipitation, 1972, Coeur d'Alene, Idaho.

Results

ENGELMANN SPRUCE

Figure 2 depicts the survival of spruce under all of the test conditions. With increasing stress, the average survival declined from 90 percent under low stress to 54 percent at moderate stress and finally to 39 percent under the severe moisture stress regime, indicating a good range of test conditions. Differences were highly significant (table 2).

Under low stress conditions (fig. 2a) stock storage regimes had no significant influence on survival for the first four planting dates. However, survival of the stock planted on June 27 was greatly influenced by storage treatment. Survival of spring-lifted stock stored in both snow cache and regular nursery storage was much lower for the June 27 planting.

Moderate stress (fig. 2b) produced a similar but less uniform pattern with significant survival differences attributable to storage evident in both the fourth and the fifth plantings. This pattern indicates that stock deterioration in storage and greater planting site stresses reduced survival.

Under extreme moisture stress (fig. 2c), the survival of spruce stock became quite erratic, but the trends established under low and moderate stress were still evident. Much of the variation in survival at the extreme stress level may have been caused by the inability to create a uniformly severe soil moisture stress due to chance soil moisture and weed competition variations.

Of particular interest was the performance of freshly lifted and planted spruce stock. Lifting and planting during late May and early June caused significantly lower survival rates than either earlier plantings or the final planting of June 27. This period of poor survival coincides with the period of rapid shoot elongation in the nursery. By June 27 elongation had probably slowed considerably and succulent new tissue had probably started to harden. Unfortunately, no data are available to test this hypothesis.

In mid-July some outstanding differences in spruce bud bursting and subsequent growth were noticed and data on bud and shoot abnormalities were gathered. For each treatment unit a count was made of abnormal terminal shoots and/or buds, and expressed as a percentage of the unit population. Since the buds of the trees from the last planting (June 27) were just beginning to break, they were not considered in this examination. Stock lifted in the spring and planted shortly afterward had by far the greatest number of abnormal terminal buds and shoots (27 percent) (table 3). Seedlings lifted in the spring and stored in refrigerators or a snow cache were intermediate in frequency of abnormal terminals (8 to 10 percent). The least abnormality occurred in seedlings lifted in November and held at 28° F (-2° C) until planted (2+ percent).

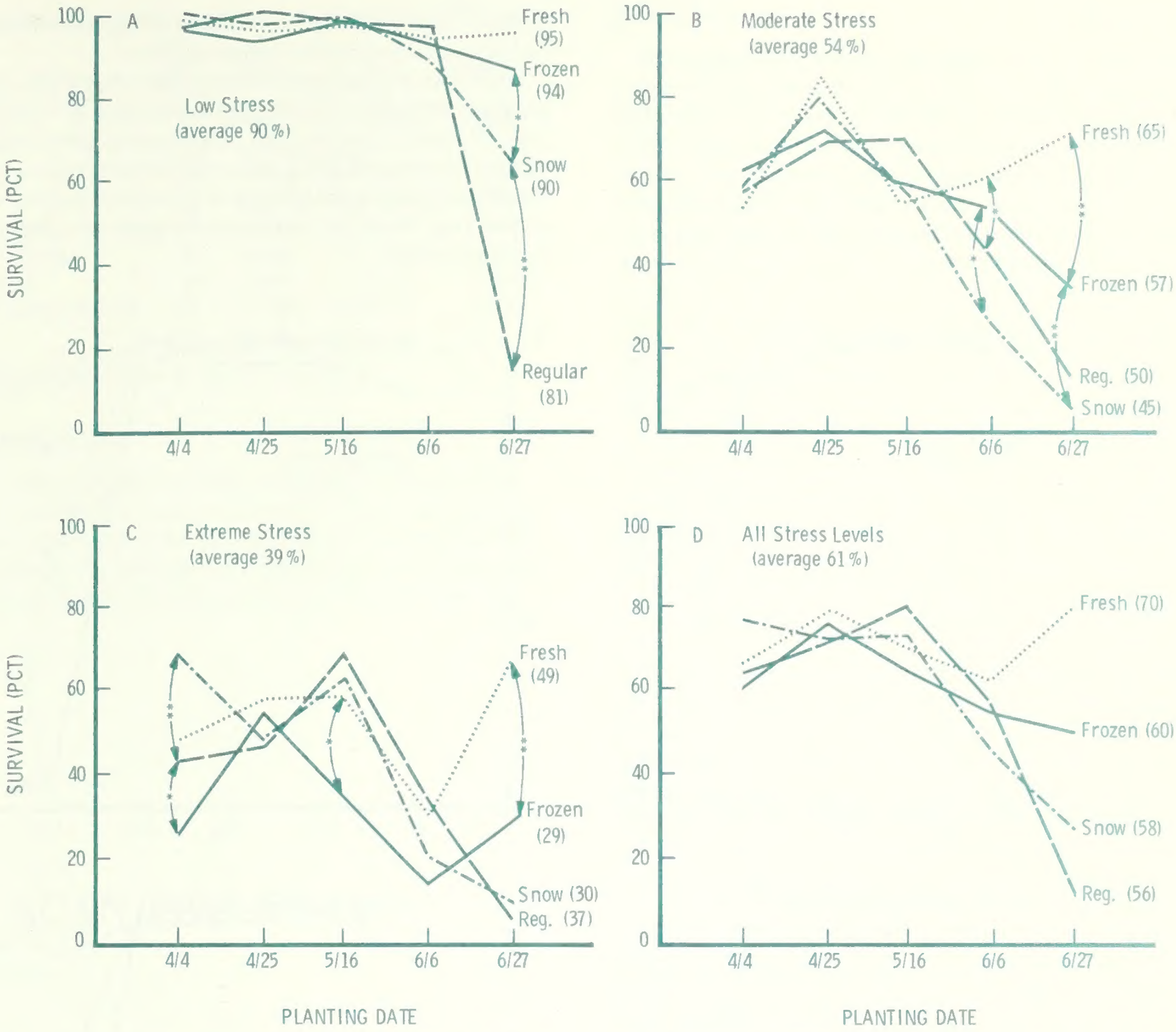

Figure 2.—First-season survival of Engelmann spruce planting stock under four storage regimes, planted throughout the spring season. Figures in parentheses are average survivals over all planting dates. Significance differences attributable to storage are shown by * and ** (p = 0.05 and 0.01, respectively) and connecting arrows.

Table 2.—Analysis of variance table, Engelmann spruce, 1972 study

Source	DF	MS	F	Prob. < F
Blocks	2	0.4222	8.3470**	0.0007
Storage	3	.2528	4.9969**	.0031
Date	4	1.0478	20.7144**	.0001
Stress	2	7.9724	157.6035**	.0001
Storage X date	12	.2704	5.3453**	.0001
Storage X stress	6	.0772	11.5252	.1750
Date X stress	8	.0887	1.7544	.0926
Storage X date X stress	24	.0300	.5925	.9308
Error	118	.0506		

**Significant at the 99 percent level of confidence.

Table 3.—Abnormal terminal buds on Engelmann spruce by storage and planting date, 1971-72

Planting date	Stock storage treatment			
	Snow	Regular	Fresh	Frozen
	Percent			
April 4	9.3	12.4	14.6	2.2
April 25	4.0	8.0	27.5	3.0
May 16	22.2	5.3	32.4	2.6
June 6	5.3	6.6	28.4	1.3
Average	10.2	8.1	26.7	2.3

LODGEPOLE PINE

The soil moisture stress levels applied in the test had no influence on lodgepole pine stock (fig. 3). Survival averaged 90 percent at all three stress levels. Obviously, the test procedures failed to create a sufficient range of moisture stress to adequately test this species. This survival tenacity of lodgepole pine under moisture stress conditions that were so devastating to spruce and larch stock was rather surprising. Previous testing of ponderosa pine, considered the most drought tolerant of species raised at the Coeur d' Alene Nursery, has resulted in very low survival rates at high stress levels (Boyd and others 1972).

Both storage regime and planting date had a highly significant effect on pine survival at all stress levels (table 4). Until the June 27 planting, survival was excellent at all stress levels and storage regimes. Stock stored in regular nursery storage virtually failed when planted in late June. Stock stored in the snow cache survived significantly better, but still compared poorly to frozen and fresh stock.

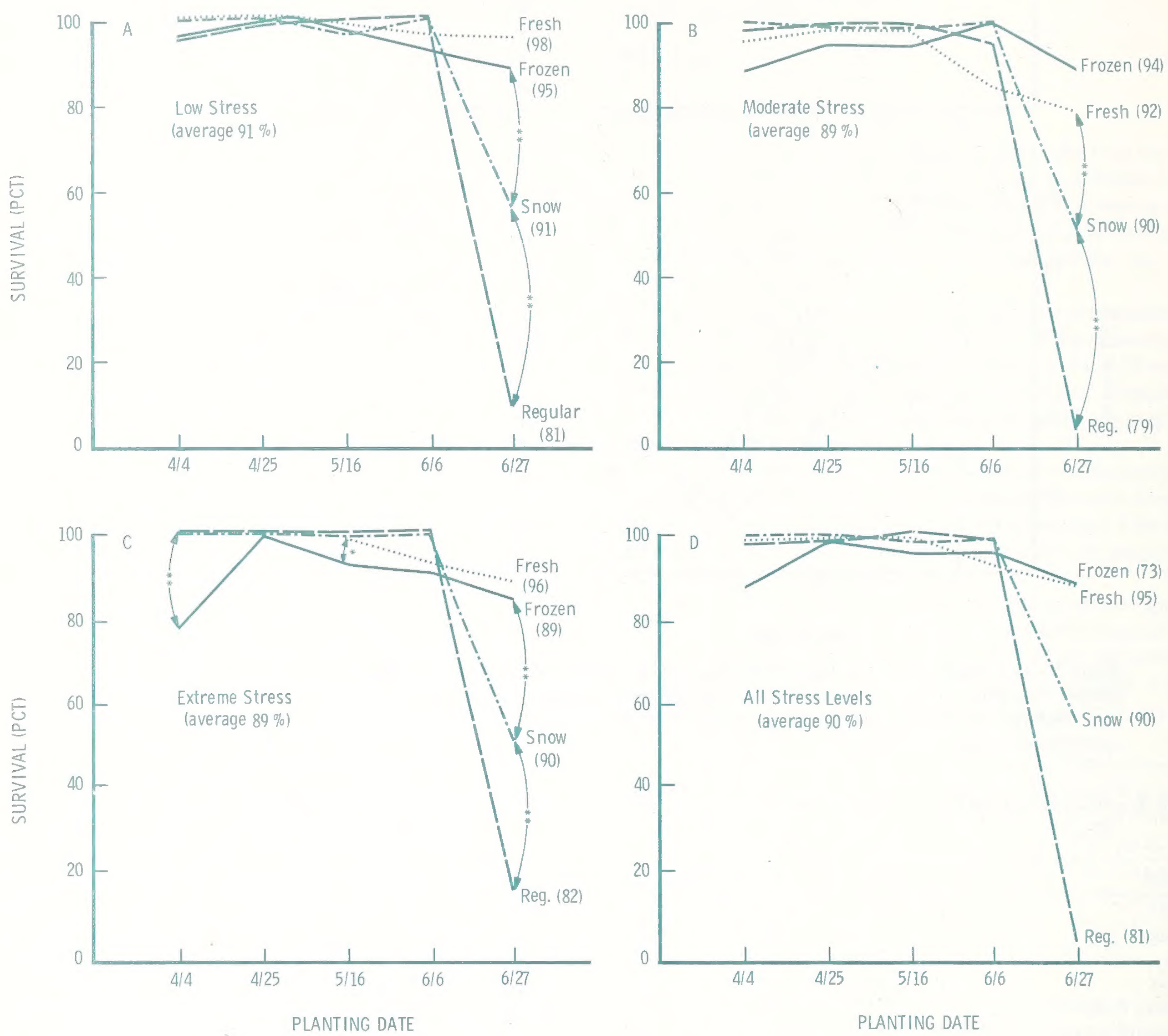

Figure 3.—First-season survival of lodgepole pine planting stock under four storage regimes, planted throughout the spring season. Figures in parentheses are average survivals over all planting dates. Significance differences attributable to storage are shown by * and ** (p = 0.05 and 0.01, respectively) and connecting arrows.

Table 4.—Analysis of variance table, lodgepole pine, 1972 study

Source	DF	MS	F	Prob. < F
Blocks	2	0.0375	2.7535**	0.066
Storage	3	.2190	16.0772**	.0001
Date	4	2.5211	185.0968**	.0001
Stress	2	.0380	2.7920	.0636
Storage X date	12	.5275	38.7251**	.0001
Storage X stress	6	.0509	3.7343**	.0023
Date X stress	8	.0061	.4500	.8886
Storage X date X stress	24	.0169	1.2417	.2214
Error	118	.0136		

**Significant at the 99 percent level of confidence.

WESTERN LARCH

All three main variables (storage, stress, and planting date) had highly significant influences on larch survival in the analysis of variance (table 5). Storage-date interaction was also highly significant; stress-date interaction was significant. Increasing stress caused a significant decline in the survival of western larch as it did with Engelmann spruce (fig. 4). At the low stress level (fig. 4a) survival generally declined when trees were planted later than the second planting (April 25) regardless of storage. Frozen stock survived exceptionally well (above 80 percent) even when planted as late as June 27. Survival of freshly lifted stock declined when planted after April 25 and reached a low of 30 percent survival at the fourth (June 6) planting, but regained its potential when lifted and planted on June 27. Snow cache and regularly stored stock survived well when planted through June 6 but failed when held until June 27 for planting.

Moderate stress reduced overall survival and, as with spruce, resulted in an expression of storage deterioration at an earlier planting date than at low stress levels (fig. 4b). Survival under moderate stress declined to unacceptable levels (30 to 50 percent) by the third planting (May 16). Survival increased from the fourth to the fifth planting with freshly lifted stock. Both fresh and frozen stock survived significantly better than regular or snow cache stock from the last planting.

Under extreme stress the same pattern prevailed but at a lower overall survival rate (29 percent) and with less overall variability in survival rates (fig. 4c).

Table 5.—Analysis of variance table, western larch, 1972 study

Source	DF	MS	F	Prob. < F
Blocks	2	0.1956	5.6845**	0.0047
Storage	3	.5000	14.5315**	.0001
Date	4	2.2613	65.7300**	.0001
Stress	2	5.2465	152.5015**	.0001
Storage X date	12	.4905	14.2583**	.0001
Storage X stress	6	.0330	.9588	.5427
Date X stress	8	.0773	2.2484*	.0282
Storage X date X stress	24	.0404	1.1749	.2787
Error	118	.0344		

*Significant at the 95 percent level of confidence.
**Significant at the 99 percent level of confidence.

Discussion

Interpretation of these results should be tempered by the realization that there is a possible confounding of stress and planting date. It was obvious by mid-July that the weed growth in areas planted in April and mid-May was more abundant and luxurious than in areas planted in June. Soil moisture monitoring was not adequate to verify any differences in soil moisture depletion associated with planting date. Nevertheless, we cannot imagine that depletion rates during the stressing period did not vary by planting date. It is also possible that there could have been inadvertent stressing of trees prior to July 1 when the planned stress cycles started. Due to weed differences associated with planting dates, this stressing could have varied with the planting date. Such a variation may account for the tendency in all species for survival to be less from the first planting than from the second planting under moderate and severe stress levels.

If the observed greater weed growth in the early plantings applied more stress to seedlings planted early and less to seedlings planted later, the effect of planting date on survival as reported in our data may be a conservative estimate. This confounding would affect the magnitude but not the direction of the observed effects.

The performance of the freshly lifted and planted stock was the most surprising result of this study. Fresh spruce and lodgepole pine stock survived as well as, or better than, all other stock at each planting date and stress level. Fresh larch stock survived poorly compared to stored stocks for the May 16 and June 6 plantings, but had the best average survival rate in the June 27 planting. Whether survival of freshly lifted stock under the conditions imposed in this study has any practical application could only be determined by further study. This type of "hot planting" may have limited utility. In this study the maximum time between lifting and planting was 1 day, hardly typical of the usual planting operation. Should longer periods of field storage have a different effect on the various stocks studied, the results of typical operational field plantings with "fresh" stock could be much different from the results of this study.

Lest the temperature of the frozen stock be considered the cause of its performance, it should be pointed out that the time at which the frozen stock was lifted may be as important or more important than the storage temperature. Stock for this treatment was lifted in a state of rest or deep dormancy before its chilling requirements had been satisfied (Romberger 1963). The relative importance of temperature and state of dormancy needs more clarification. The low incidence of abnormal terminal buds and shoots in frozen spruce stock suggests that: (1) bud chilling requirements are not being satisfied with normal overwinter nursery field climate, lifting, and storage regimes, or (2) spring lifting and storage procedures upset the normal pattern of activity and growth.

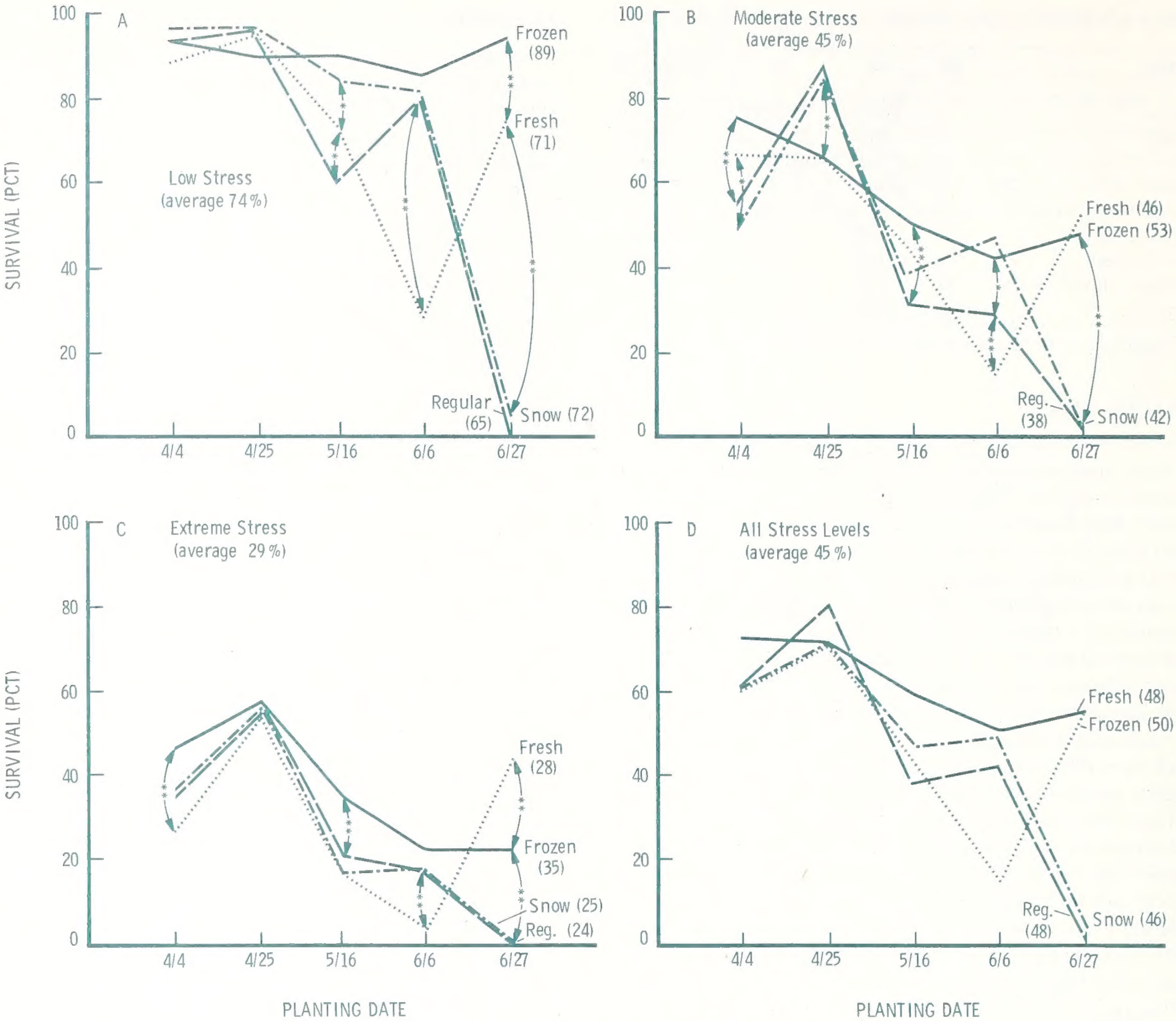

Figure 4.—First-season survival of western larch planting stock under four storage regimes, planted throughout the spring season. Figures in parentheses are average survivals over all planting dates. Significance differences attributable to storage are shown by * and ** (p = 0.05 and 0.01, respectively) and connecting arrows.

PHASE II. FIELD SURVIVAL AND GROWTH TESTS, 1973

While the 1972 moisture stress plot evaluation of the storage regimes and planting dates provided some valuable leads, testing under field conditions was needed to verify trends. The validity of the moisture stress plot technique also needed testing, especially when planting date was a study variable. Consequently, a small, single-season field test was installed on the Coeur d'Alene National Forest in 1973.

Methods

The same three species (Engelmann spruce, lodgepole pine, and western larch) were tested. Storage treatments were frozen, refrigerated, and fresh, all conducted in the same manner as in the 1972 study. Snow cache storage was omitted in the interest of economy—we felt that the technique already had been adequately field tested. Stock for overwinter storage was lifted between November 27 and December 1, 1972, preconditioned at 34° to 38° F (1° to 3° C) until December 7, then packed in 4-mil polyethylene bags, sealed, and placed in 28° F (–2° C) storage until removed for planting. All trees for regular refrigerated storage were lifted on March 19, 1973, packed in polyethylene-lined Kraft bags, and placed in 34° to 38° F (1° to 3° C) storage. All frozen stock was removed from storage 4 to 5 days prior to planting and held at 34° to 38° F (1° to 3° C) until the day of planting. Fresh stock was lifted the day before planting (table 6).

A total of 3,600 trees were planted, 1,200 of each species, in 100-tree lots, each with a specific treatment/species/planting date combination. Each lot was planted in two 50-tree rows separated by the other rows of species and treatments for that planting date. Spacing of trees was approximately 3 ft by 3 ft (1 m by 1 m). All trees were hand planted in auger-drilled holes. Each tree was staked and identified to allow accurate survival checks.

The study site provided uniformity of soil, aspect, and site preparation treatment. The area is approximately 8 miles east of

Table 6.—Length of nursery stock storage, in days, prior to planting, 1972-73

Planting date, 1973	Storage method and length of storage: Refrigerated	Frozen	Fresh
	Days		
April 18	30	140[1]	None
May 9	51	161	None
May 30	72	182	None
June 20	93	203	None

[1]Approximate; seedlings were lifted between November 27 and December 1, 1972 (135 to 139 days prior to April 18).

Coeur d'Alene, Idaho. It was logged in 1971, slashed, and prescribed broadcast burned in 1972. Burning was quite complete with all small slash consumed; a number of small logs on the ground were charred and not completely burned. The site is typical of the grand fir/pachistima habitat type (Daubenmire and Daubenmire 1968). West and north aspects were represented. Western larch and lodgepole pine were planted in one block on a uniform west aspect while the spruce was planted on a northerly aspect.

The summer of 1973 was extremely dry and hot compared to normal weather for the area (fig. 5). April through August precipitation was 51 percent of normal. Such weather was favorable for the field test because application of a high degree of moisture stress to the seedlings was desirable.

Survival was checked at the end of the first and third growing seasons (1973 and 1975). The total height of sample trees (every third survivor) was measured in the fall of 1975 to the nearest inch. Third-year survival, third-year height, and stem production (stem length produced per 100 planted trees) were analyzed by standard analysis of variance procedures for a factorial design. Species was included in the analysis as a main effect variable. Results of the analysis are shown in figures 6 through 14. Analysis of variance statistics are summarized in tables 7 through 9.

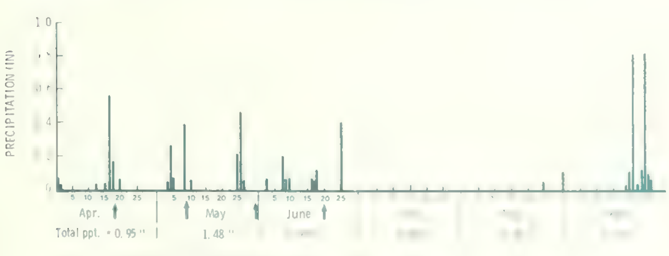

Figure 5.—Growing season precipitation, 1973, Coeur d'Alene, Idaho.

Results

ENGELMANN SPRUCE

Survival (fig. 6).—Average overall survival of spruce was 58 percent, significantly lower than survival of larch and lodgepole pine. This probably doesn't reflect true spruce potential, since the site was marginal for spruce. Survival ranged from 91 percent to 29 percent with a general decline as the planting season progressed. With an average survival of 82 percent, the April 18 planting survival was significantly better than the survival of the May 9 planting (62 percent survival) which was significantly better than the two later plantings (44 percent and 45 percent survival). For all planting dates survival was best with refrigerated (65 percent) and frozen (61 percent) stock. Fresh stock averaged only 50 percent survival. The survival of the May 9 plantings was probably depressed by an unusually warm, dry period of 13 days following planting, a natural factor that did not occur in the previous experiment in the moisture stress plots.

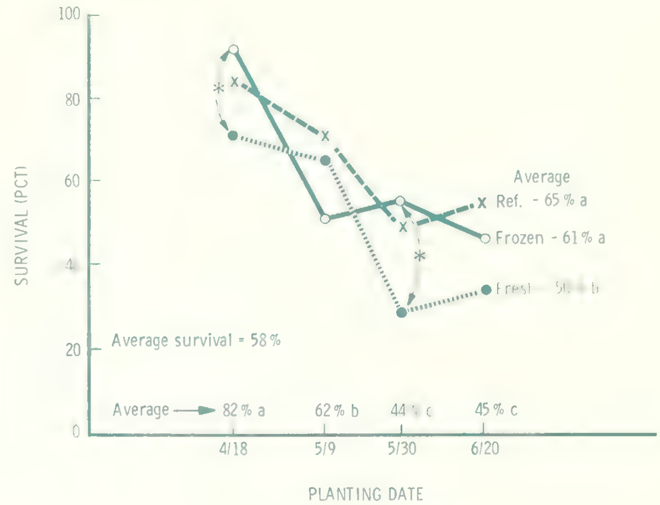

Figure 6.—Effects of storage regime and planting date on third-year survival of field-planted Engelmann spruce stock. Average survival percentages (in a row for planting date and, for storage treatment, in a column) followed by the same letter are not significantly different (p = 0.05). Survival percentage levels, within a planting date, connected by arrows with an accompanying asterisk are significantly different (p = 0.05).

Table 7.—Analysis of variance for survival, 1973 field trials

Source	DF	MS	F	Prob. < F
Replication	1	3.1250	0.1407	0.7110
Species	2	549.0556	24.7203**	.0001
Storage	2	218.0556	9.8176**	.0007
Planting date	3	1,089.9398	49.0727**	.0001
Species X storage	4	35.2639	1.5877	.1984
Species X planting date	6	105.6481	4.7566*	.0015
Storage X planting date	6	54.4259	2.4504*	.0435
Species X storage X planting date	12	42.8009	1.9270	.0648
Error	35	22.2107		

*Significant at the 95 percent level of confidence.
**Significant at the 99 percent level of confidence.

Table 8.—Analysis of variance for plant height, 1973 field trials

Source	DF	MS	F	Prob. < F
Replication	1	4.0139	0.7453	0.6019
Species	2	1,339.1885	248.6608**	.0001
Storage	2	38.2001	7.0930*	.0029
Planting date	3	137.7046	25.5690**	.0001
Species X storage	4	16.8481	3.1284*	.0263
Species X planting date	6	33.2164	6.1676*	.0003
Storage X planting date	6	6.9492	1.2903	.2866
Species X storage X planting date	12	5.0360	.9351	.5247
Error	35			

*Significant at the 95 percent level of confidence.
**Significant at the 99 percent level of confidence.

Table 9.—Analysis of variance for stem production, 1973 field trials

Source	DF	MS	F	Prob. < F
Replication	1	0.9239	0.1040	0.7475
Species	2	780.3405	87.8789**	.0001
Storage	2	127.3136	14.3376**	.0001
Planting date	3	451.0427	50.7947**	.0001
Species X storage	4	25.1816	2.8358*	.0383
Species X planting date	6	65.4484	7.3705**	.0001
Storage X planting date	6	24.9826	2.8134*	.0241
Species X storage X planting date	12	14.5019	1.6331	.1271
Error	35	310.7904	8,8797	

*Significant at the 95 percent level of confidence.
**Significant at the 99 percent level of confidence.

Growth (fig. 7).—Three years after planting, the average height of the surviving spruce trees was 15 inches (38.10 cm), ranging from 11 inches (27.94 cm) to 18 inches (45.72 cm). For all storage treatments, trees from the April 18 planting were taller than trees planted on June 20 (17 inches [43.18 cm] vs. 13 inches [33.02 cm]). There was no significant difference in the average height that could be attributed to storage treatment.

Stem production (fig. 8).—Planting date strongly influenced spruce stem production. Over the 3-year period, average production per 100 planted trees ranged from 116 ft (35.36 m) for the April 18 planting to 49 ft (14.93 m) for the June 20 planting. Production extremes varied from 35 ft (10.67 m) for fresh stock planted on May 30 to 135 ft (41.15 m) for frozen stock planted on April 18. Storage treatment, averaged over all planting dates, also had a significant influence on productivity, with fresh stock producing much less (59 ft [17.98 m]) than either frozen (77 ft [23.47 m]) or refrigerated (85 ft [25.91 m]) stock.

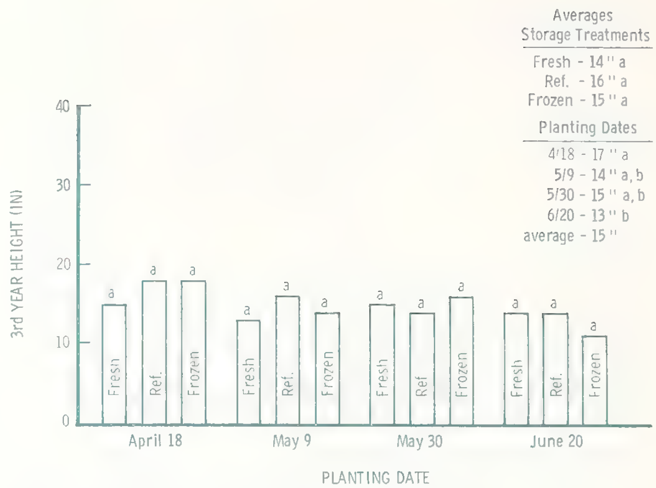

Figure 7.—Effects of storage regime and planting date on third-year height of field-planted Engelmann spruce stock. Columns, within a planting date group, topped by the same letter are not significantly different (p = 0.05). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different (p = 0.05).

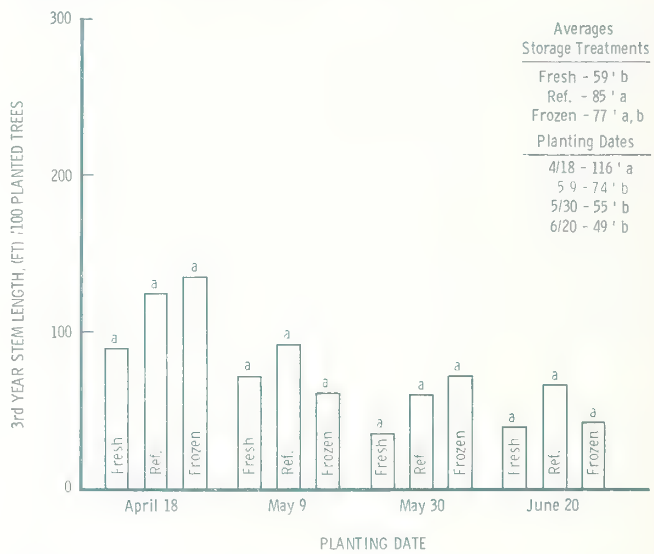

Figure 8.—Effects of storage regime and planting date on third-year stem production of field-planted Engelmann spruce stock. Columns, within a planting date group, topped by the same letter are not significantly different (p = 0.05). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different (p = 0.05).

LODGEPOLE PINE

Survival (fig. 9).—Average lodgepole pine survival was 77 percent, and ranged from a low of 51 percent to a high of 96 percent. Average survival of frozen and regular stock over all planting dates was over 80 percent, significantly better than survival of fresh stock (69 percent). This difference was due to the relatively poor survival of fresh stock planted on May 9, 30, and June 20. Survival declined as the plantings were delayed, but the decline was not as severe as it was with spruce (fig. 6) and larch (fig. 12).

Growth (fig. 10).—The 3-year height of lodgepole pine averaged 21 inches (53.34 cm) and ranged from 17 inches (43.18 cm) to 25 inches (63.50 cm). Refrigerated stock was significantly taller (23 inches [58.42 cm]) than the fresh stock (20 inches [50.80 cm]), but not significantly taller than the frozen stock (21 inches [53.34 cm]). Stock planted on June 20 was 5 to 6 inches (12.70 to 15.24 cm) shorter than trees planted earlier in the planting season.

Stem production (fig. 11).—Lodgepole pine averaged 140 ft (42.67 m) of stem production per 100 planted trees in the 3-year period, ranging from 70 ft (21.33 m) to 190 ft (57.91 m). When totals, by treatment, for all planting dates were averaged, refrigerated stock production was highest (160 ft [48.77 m]) and fresh stock the lowest (112 ft [34.14 m]). Frozen stock averaged 145 ft (44.19 m) of stem growth per 100 planted trees. Production from fresh stock was definitely inferior to that from refrigerated and frozen stock for all except the April 18 planting. Stem production for the June 20 planting (89 ft [27.13 m]) was considerably below that for earlier plantings (135–173 ft [41.15–52.73 m]).

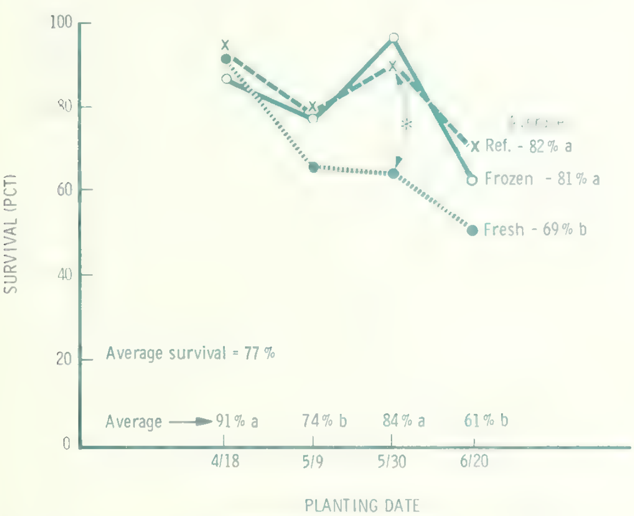

Figure 9.—Effects of storage regime and planting date on third-year survival of field-planted lodgepole pine stock. Average survival percentages (in a row for planting date and, for storage treatment, in a column) followed by the same letter are not significantly different (p = 0.05). Survival percentage levels, within a planting date, connected by arrows with an accompanying asterisk are significantly different (p = 0.05).

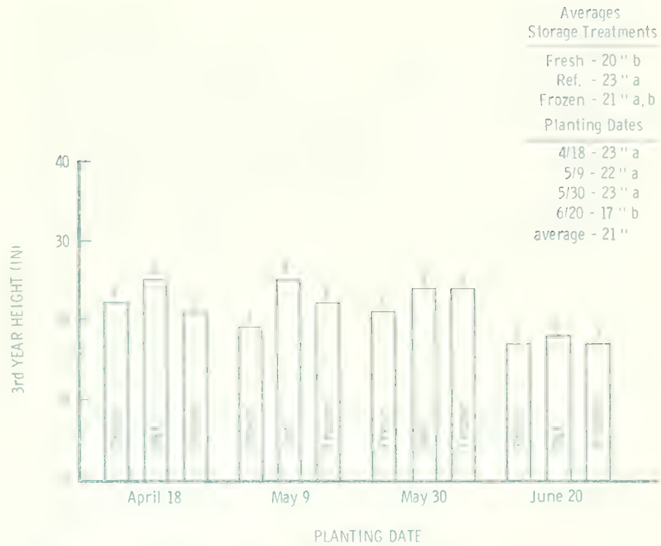

Figure 10.—Effects of storage regime and planting date on third-year height of field-planted lodgepole pine stock. Columns, within a planting date group, topped by the same letter are not significantly different (p = 0.05). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different (p = 0.05).

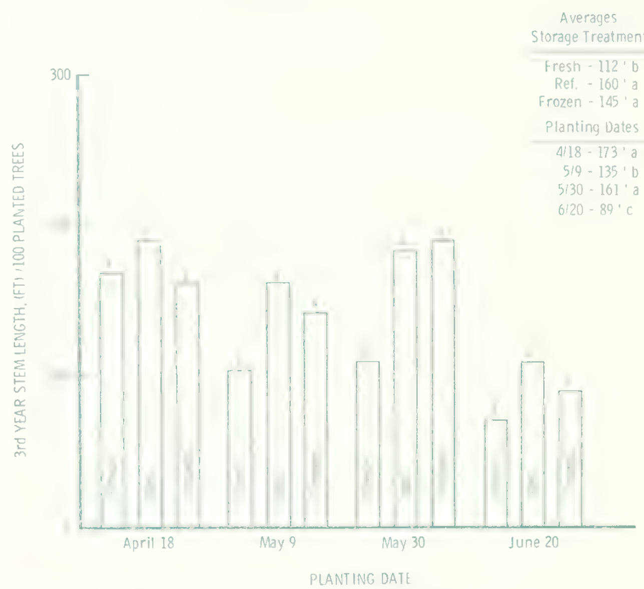

Figure 11.—Effects of storage regime and planting date on third-year stem production of field-planted lodgepole pine stock. Columns, within a planting date group, topped by the same letter are not significantly different (p = 0.05). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different (p = 0.05).

WESTERN LARCH

Survival (fig. 12).—The overall survival of western larch after 3 years was 65 percent, ranging from 33 percent to 94 percent. Both storage method and planting date have had a strong effect upon survival. For all planting dates the larch stored over winter in frozen condition survived better (71 percent) than either fresh or refrigerated stock (both 62 percent), but these differences were not statistically significant. Survival of the April 18 planting (87 percent) was significantly better than all other plantings; survival of the June 20 planting (39 percent) was significantly poorer than all others.

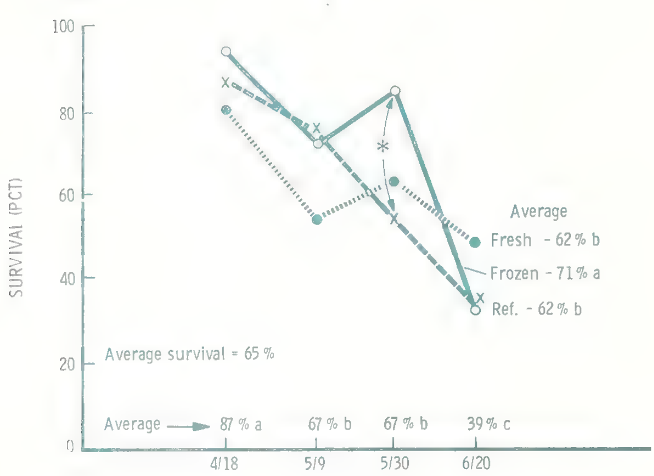

Figure 12.—Effects of storage regime and planting date on third-year survival of field-planted western larch stock. Average survival percentages (in a row for planting date and, for storage treatment, in a column) followed by the same letter are not significantly different ($p = 0.05$). Survival percentage levels, within a planting date, connected by arrows with an accompanying asterisk are significantly different ($p = 0.05$).

Growth (fig. 13).—Growth averaged 30 inches (76.20 cm) for all storage and planting date treatment combinations, with a range from 21 inches (53.34 cm) to 37 inches (93.98 cm). For all planting dates, frozen stock grew best (33 inches [83.82 cm]) and fresh stock grew poorest (27 inches [68.58 cm]). Planting date had an even stronger influence. Growth ranged from 32 to 36 inches (81.28 to 91.44 cm) for the April 18 and May 9 plantings, to 23 inches (58.42 cm) for the late June planting. Frozen stock consistently had the greatest third year height, and fresh stock was almost as consistently the shortest after 3 years. The effects of late planting in reduced height growth were more pronounced with fresh and refrigerated storage stock than with the frozen stock.

Stem production (fig. 14).—Larch averaged 168 ft (51.20 m) of stem production per 100 planted trees, and ranged from 278 ft (84.73 m) to 59 ft (17.98 m). When stem production was averaged over all planting dates, frozen stock outproduced refrigerated and fresh stock by a wide margin (201 ft [61.28 m] vs. 162 ft [49.38 m] and 141 ft [42.97 m], respectively). Averaged over all storage treatments, growth ranged from 232 ft (70.71 m) for the April 18 planting, to 74 ft (22.55 m) for the June 20 planting.

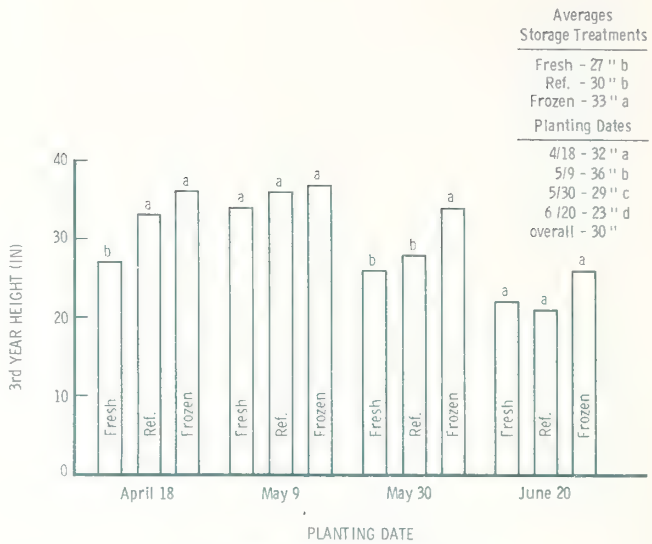

Figure 13.—Effects of storage regime and planting date on third-year height of field-planted western larch stock. Columns, within a planting date group, topped by the same letter are not significantly different ($p = 0.05$). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different ($p = 0.05$).

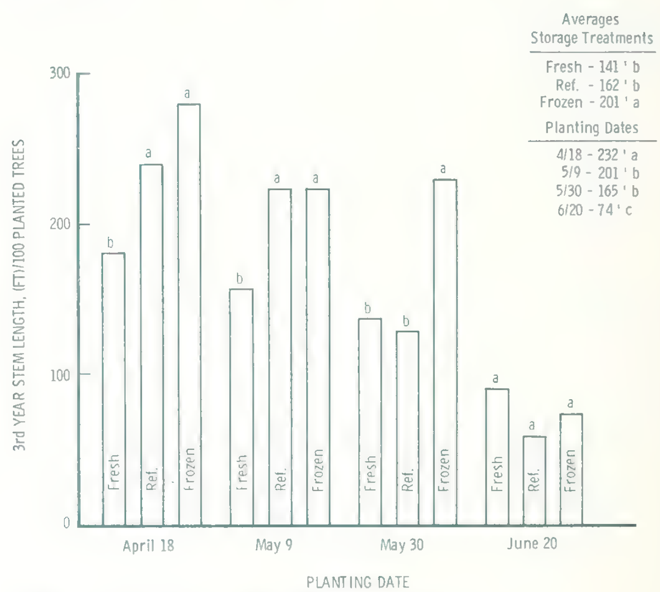

Figure 14.—Effects of storage regime and planting date on third-year stem production of field-planted western larch stock. Columns, within a planting date group, topped by the same letter are not significantly different ($p = 0.05$). Averages, of storage treatments or planting dates, followed by the same letter are not significantly different ($p = 0.05$).

Discussion

Results from both tests reported on here show that overwinter storage of planting stock at subfreezing temperatures results in survival and growth rates equal to or better than those obtained with conventional spring lift-cold storage procedures. In only a few situations was the survival of frozen stock significantly less than that of regular stock. Moisture stress plot test results were not completely verified by the field tests, however. In the field test, survival of late planted frozen and fresh stock did not exceed the survival of regular stock as in the moisture stress plot test. The difference in results can probably be attributed to the failure of the stress plot test to provide for decreasing soil moisture supply for the later planting. It was thought that keeping the stress plots at relatively high soil moisture levels until July 1 would emulate natural precipitation and soil moisture conditions in the field. Either this was not true, or the postplanting soil moisture depletion in the field was more rapid than in the stress plots. Of course, both factors could have contributed to the differences.

Because of this difference, the stress technique as used here is not recommended for tests that involve variations in planting date. A stress plot test using a modified physical arrangement and improved soil moisture monitoring and control is feasible, however.

Operationally, the frozen storage technique has great potential value for spreading nursery work, especially stock lifting and packing, over a longer time span. This could result in increased efficiency of operation and better utilization of nursery facilities. Furthermore, seedlings can be lifted in a fully dormant condition and stored at temperatures which effectively retard fungal activity. Complete satisfaction of chilling requirements may be an additional benefit.

Seedlings which must be stored until high elevation sites open late in the planting season also store better frozen. Freshly lifted stock, which has neared or reached the end of the initial rapid shoot elongation period in the spring, has good survival potential only if unusually good soil moisture and atmospheric conditions prevail following planting.

RECOMMENDATIONS

1. Frozen storage over winter of Engelmann spruce, lodgepole pine, and western larch, in the manner described, simulates natural overwinter conditions. It is feasible and offers important advantages over other storage methods, especially for stock to be planted late in the planting season.
2. Regardless of the storage regime used, early planting results in better survival and subsequent growth. Fall lifting and overwinter storage should facilitate early planting, especially in years when weather conditions preclude early lifting of stock at the nursery.
3. Frozen storage is probably extendable to other western conifers. Validation of this assumption is needed.
4. Planting freshly lifted stock late in the planting season, after most stem elongation has taken place, is biologically feasible, but operationally difficult. Such planting may give survival rates well above those of trees coming out of long-term storage, but fresh stock of this sort must be replanted very soon after lifting to avoid severe mortality. Such stock must be treated delicately in the interval between lifting and planting. It is better to plant dormant trees early in the season for both growth and survival.
5. More study is needed to determine the effects of fall lifting dates on the survival and growth potential of stock stored over winter and on methods to determine when stock is physiologically ready for lifting. Until information is available, it is recommended that stock not be lifted prior to November 1 or until there is suitable evidence that the stock is "dormant" and that food reserves are at a high level. The current practice at the Coeur d'Alene Nursery involves testing the plants' activity status using the oscilloscope technique described by Ferguson and others (1975). Plants are not lifted until 2 weeks after they show a "dormant" oscilloscope trace.
6. The described frozen storage may provide for more complete satisfaction of the "chilling requirements" of Engelmann spruce buds leading to more normal bud break and shoot growth than that obtained with other lifting and storage procedures.
7. Methods and studies of overwinter cold storage of nursery stock are well documented and the procedure can be made operational in most cases if cold storage facilities are available.

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In two studies in northern Idaho, nursery stock was lifted and stored under a variety of regimes and planted throughout the spring planting season. Planting date had the strongest influence on survival and growth, with early plantings performing better than late plantings.

KEYWORDS: conifer seedlings, lifting, storage, planting date

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